Chlorination and Arsenic Treatment

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Utah Division of Drinking Water
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Presentation Topics

- 3 Types of Chlorination
  1. Chlorine (Gas)
  2. Sodium Hypochlorite (Liquid)
     - Injection/Dilution
     - On-site Generation
  3. Calcium Hypochlorite (Tablet/Granule/Powder)
- Arsenic
- Arsenic Compliance Strategies

Different Types of Chlorine

Gas - Chlorine
$Cl_2 + H_2O \rightarrow$ **HOCl** + HCl

Bleach - Sodium Hypochlorite
$NaOCl + H_2O \rightarrow$ **HOCl** + NaOH

Powder/Tablets - Calcium Hypochlorite
$Ca(OCl)_2 + 2H_2O \rightarrow$ 2**HOCl** + $Ca(OH)_2$

- All three forms of chlorine will react with water to form ***hypochlorous acid (HOCl)***

Disinfection Rule (R309-520)

- Chlorine (R309-520-7)
  - Gaseous chlorine
  - Calcium hypochlorite
  - Sodium hypochlorite liquid
  - Sodium hypochlorite on-site generation
- UV
- Ozone
- Chlorine Dioxide
- Chloramines

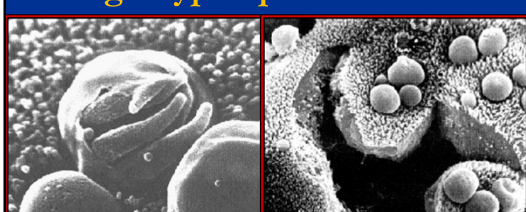
Disinfection Rule - General

- **<u>Primary</u> Disinfectant**
  - Chlorine, Ozone, UV, Chlorine Dioxide
  - Treatment process
  - CT & UV dose
- **<u>Secondary</u> Disinfectant**
  - Chlorine & Chloramines
  - Maintain residual in distribution system
- Continuous Disinfection (Surface water & GWUDI)
- ANSI/NSF Standard 60 certified chemicals

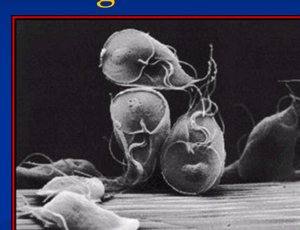
Disinfection Rule - General

- **Bin 1 Surface Water**

2-log Cryptosporidium

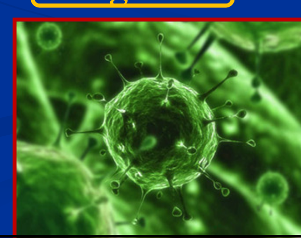


3-log Giardia



E. Coli Monitoring

4-log virus



Chlorine Rule — General

- **Automatic proportioning**
- **Minimization of chlorinated overflow**
- **Chlorination facility design**
  - Heating, lighting, ventilation
  - Feed water piping, flow measurement
  - Standby and backup equipment
  - Bypass-to-waste and isolation
  - Chlorinator capacity

Chlorinator Design & Required CT

- **CT → Concentration and Time**
- **4-log virus inactivation → CT=12**
- **High quality GW source**
  - CT of 12 not required when adding new chlorinator
  - Recommended
- **Questionable GW source**
  - CT of 12 is required when adding new chlorinator
  - May need additional storage or special configuration
- **Booster chlorinator for distribution system**
  - CT of 12 not required
  - Maintain disinfection residual

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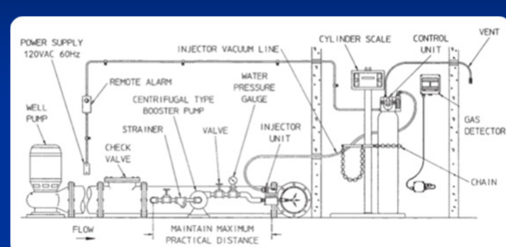
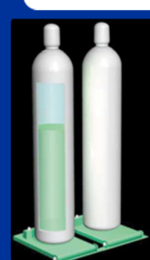
Gas Chlorination





Gas Chlorine

Additional Requirements in R309-520-7(2)

- Automatic switch over
- Heating and ventilation
- Injector and eductor
- Housing
- Cylinder security
- Weighing scales
- Pressure gauges

Gas Chlorination

- Low chemical cost
- Low maintenance cost
- Shipped and stored in same container
- Easy to regulate / measure feed rates
- Chlorine concentration constant

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Sodium Hypochlorite Chlorination

Sodium Hypochlorite Chlorination
R309-520-7(3)(a)

- ANSI/NSF 60 chemicals
- Emergency eyewash/shower
- Minimize decay

Sodium Hypochlorite Chlorination

- Readily available chemical
- 5-15% Strength
- Relatively non-lethal
- Generally inexpensive feed equipment

Sodium Hypochlorite Chlorination
Pumps

Solenoid

Peristaltic

Stepper Motor

Mechanically Actuated

Sodium Hypochlorite Chlorination
Dilution

- Dilute to Any Strength
- Minimal Space Requirements
- Pre-Engineered Systems

Sodium Hypochlorite Chlorination Dilution

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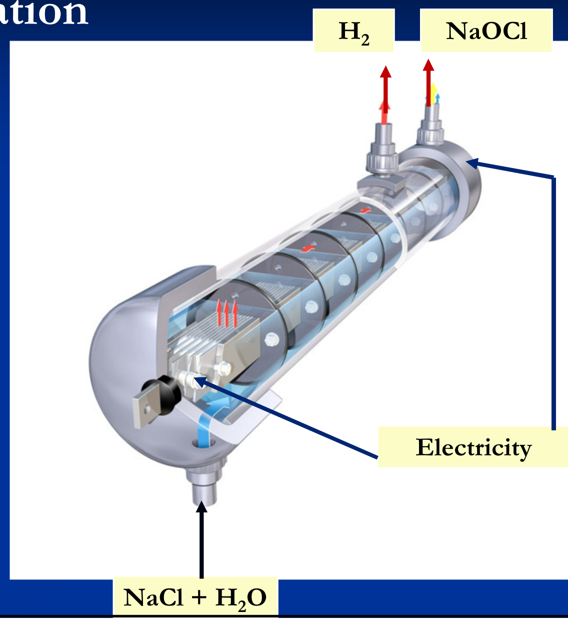
Sodium Hypochlorite Chlorination

On-site Generation

R309-520-7(3)(b)

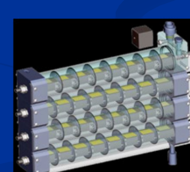
- ANSI/NSF 61
- ANSI/NSF 60

✓ Safety



Sodium Hypochlorite Chlorination

On-Site Generation



Sodium Hypochlorite Chlorination
On-Site Generation

- 0.8% Strength
- Variety of generation capacities
- Flexible installation
- Visual indication of cell operation

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Calcium Hypochlorite Chlorination

Powder/Tablet Feeders

Calcium Hypochlorite Chlorination

R309-520-7(3)(c) and (d)

- Calcium Hypochlorite
  - Tablet, Granule, Powder
  - ANSI/NSF 60 chemicals
  - Storage & Safety
  - Operation & Maintenance
- Hypochlorite Feed Equipment
  - ANSI/NSF 61 materials
  - Exception

Calcium Hypochlorite Chlorination

- Long shelf life: (~5% loss/year)
- Minimal chlorate formation
- Easy to transport and store
- Spills/leak less likely
- NSF Standard 60 Certified

Which to Choose

- Not dictated by the State
- Operator's Experience & Skill
- Cost
- East of Handling & Maintenance
- Safety
- Foot Print
- Existing Facility
- Power Availability
- Location

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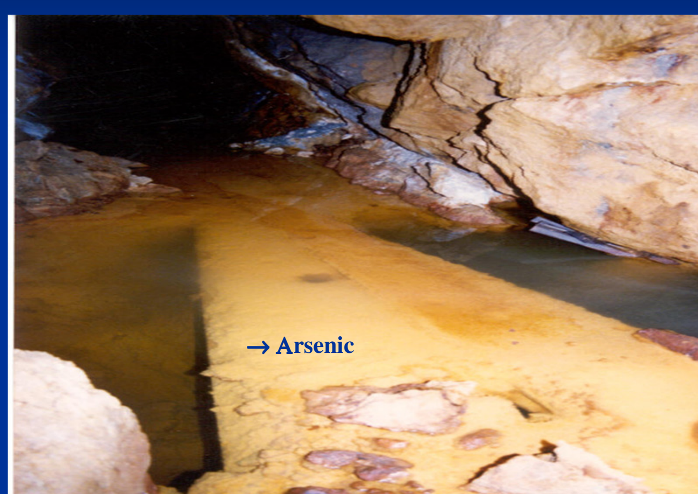
Arsenic



Arsenic

- Maximum Contaminant Level (MCL) at 10.0 ug/L (10.0 ppb)
- MCL based on <u>chronic</u> health effects
- Multiple oxidation states
  - Arsenite (III)
  - Arsenate (V)

$$As^{3+} \longrightarrow As^{5+} + 2e^-$$

Arsenic Speciation

- Theoretically, As (V) in surface water & As (III) in ground water.
- Oxidize As (III) to As (V) before applying treatment.
  - As (III) has higher toxicity
  - As (V) is more effectively removed by most treatment technologies

Oxidize As (III) to As (V)

- Effective Oxidants
  - ✓ Free Chlorine
  - ✓ Potassium Permanganate
  - ✓ Ozone
- Ineffective
  - ✓ Chloramines, Chlorine Dioxide, UV, Aeration
- Point of oxidant application is important

How Are Utah Water Systems Affected?

- 37 Utah water systems' water sources exceed arsenic MCL (10.0 ug/L)
- 16 Counties affected
  - Millard (7 water systems)
  - Salt Lake (6)
  - Box Elder (4)
  - Wayne (3)

EPA Decision Tree Overview

- Step 1: **Water Quality Monitoring**
- Step 2: **Blending**
- Step 3: **Optimizing Existing Treatment**
  - Enhanced Coagulation/Filtration
  - Enhanced Lime Softening
  - Iron & Manganese Filtration
- Step 4: **Selecting New Treatment**
  - Ion Exchange Processes
  - Adsorption Processes
  - Membrane Processes

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- **Arsenic**
- **Arsenic Compliance Strategies**

Arsenic Compliance Options

1. Abandon source or develop alternate source
2. Sample averaging
3. Blend with other sources
4. Combination of blending & averaging
5. Point of use/point of entry device
6. Central treatment

Blend with Other Sources

- Identify flow and arsenic level of possible sources
- Compare blended concentration with MCL
- Evaluate system layout, blending mechanism and sampling location (before 1st customer)
- Construction or SCADA may be needed
- Blending plan must be reviewed and approved

Point of Use (POU)

POU/POE for Arsenic Removal

- All homeowners agree (100% participation)
  - Public meeting on costs and options
  - If POU is the majority position, a POU unit installed at each kitchen tap & water user allows PWS the access for servicing of units
- Only some taps treated
- Rotating sampling sites within the PWS
- O&M and replacement
- PWS sends operation reports to DDW
- Using POU/POE for arsenic compliance must be reviewed and approved

Point of Use Technologies

- Ion exchange
- Activated alumina
- Granular ferric hydroxide
- Reverse Osmosis (RO)

Reverse Osmosis POU

Arsenic Compliance Options

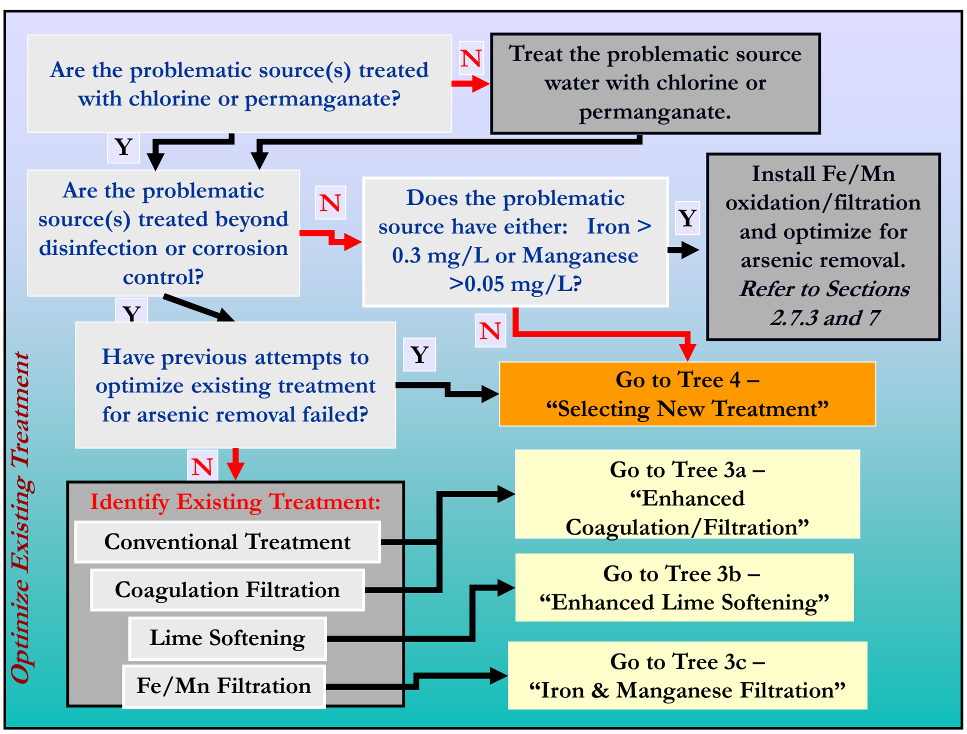
1. Abandon source or develop alternate source
2. Sample averaging
3. Blend with other sources
4. Combination of blend & averaging
5. Point of use/point of entry device
6. Central treatment

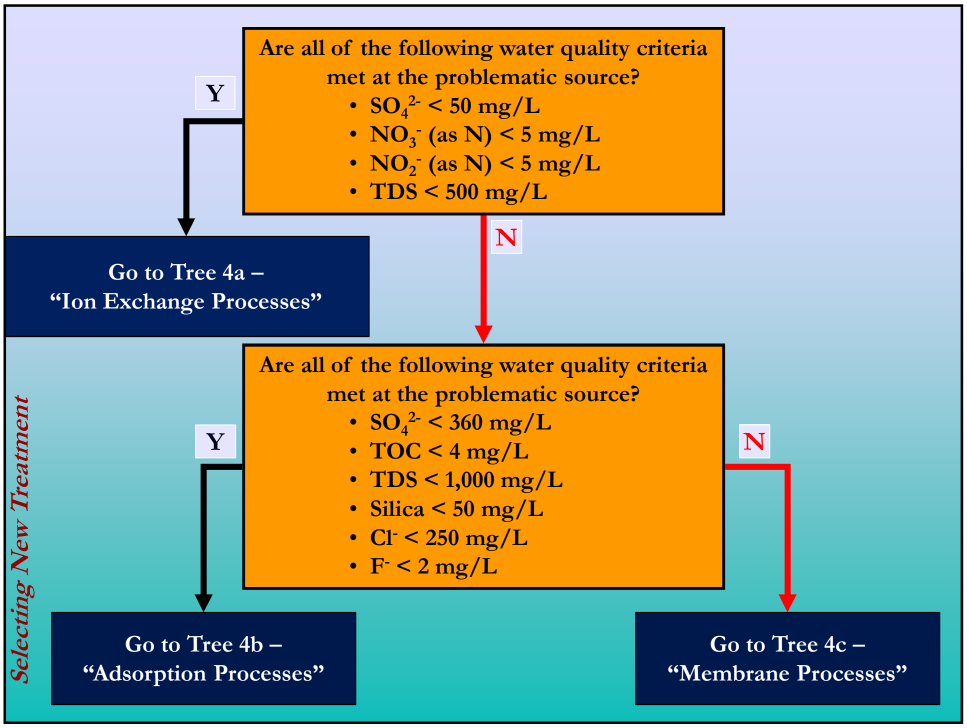
Arsenic Mitigation in Utah

1. Abandon source or develop alternate source (4 water systems)
2. Sample averaging (2)
3. Blend with other sources (9)
4. Combination of blend & averaging (2)
5. POU (8) & POE (0)
6. Central treatment (10)
7. No longer PWS (1)

EPA Decision Tree Overview

- Step 1: Water Quality Monitoring
- Step 2: Blending
- Step 3: **Optimizing Existing Treatment**
  - **Enhanced Coagulation/Filtration**
  - **Enhanced Lime Softening**
  - **Iron & Manganese Filtration**
- Step 4: **Selecting New Treatment**
  - **Ion Exchange Processes**
  - **Sorption Processes**
  - **Membrane Processes**





Optimization of Existing Process

1. Enhanced Coagulation/Filtration
2. Enhanced Lime Softening
3. Iron and Manganese Removal
   - Oxidation/Filtration

Optimization of Existing Process

To Increase Arsenic Removal

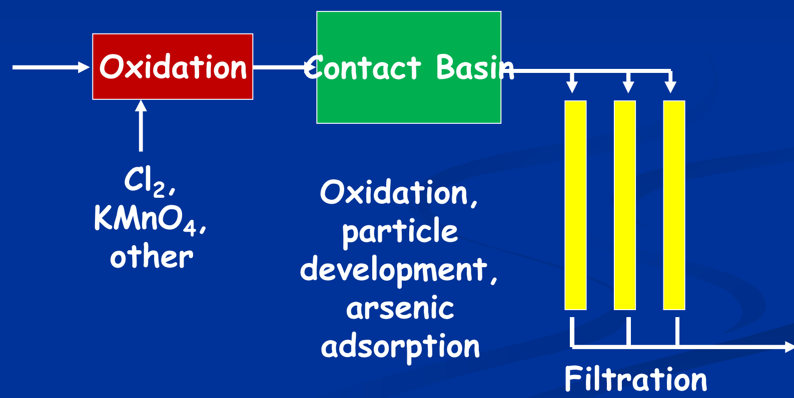
Utility with existing <u>iron removal</u> process and not meeting 10.0 ppb:

1. Increase iron concentration
2. Adjust pH
3. Replace arsenic adsorption media
4. Change point of oxidant addition

Iron-Based Arsenic Removal Process

- Adsorptive properties of iron mineral toward arsenic
- Arsenic treatment processes:
  - ✓ Iron Removal
  - ✓ Coagulation with iron coagulant
  - ✓ Iron-based adsorption media

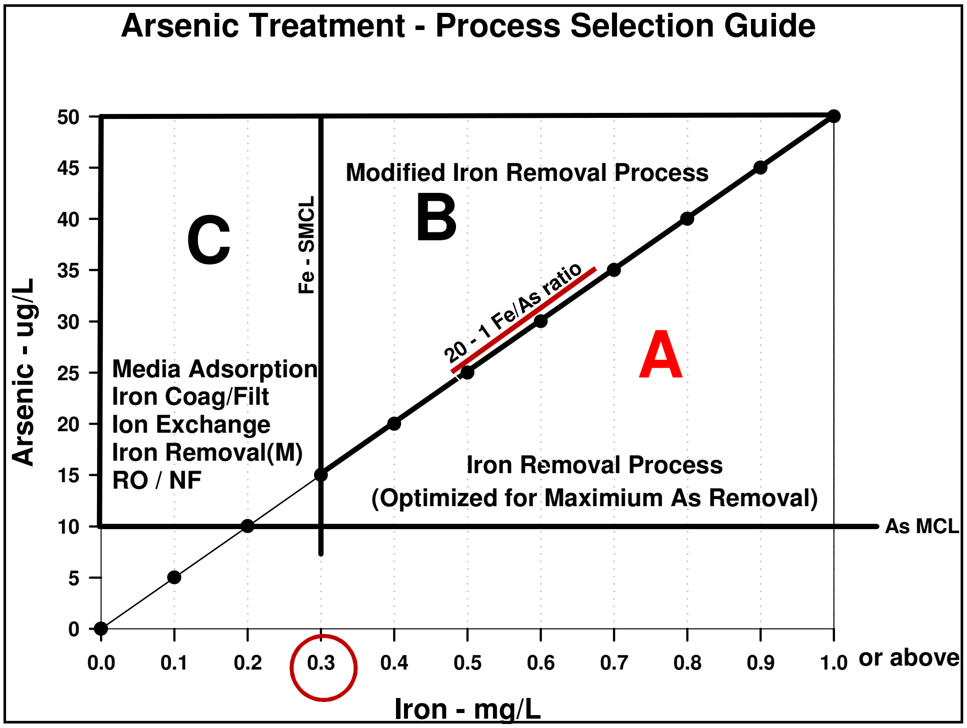
Iron and Arsenic (& Mn) Removal



Iron-Based Arsenic Removal Process

Removal of 1 mg/L of iron
achieves
removal of 50 ug/L arsenic

* Optimized conditions and 100% As (V)



Installation of New Treatment

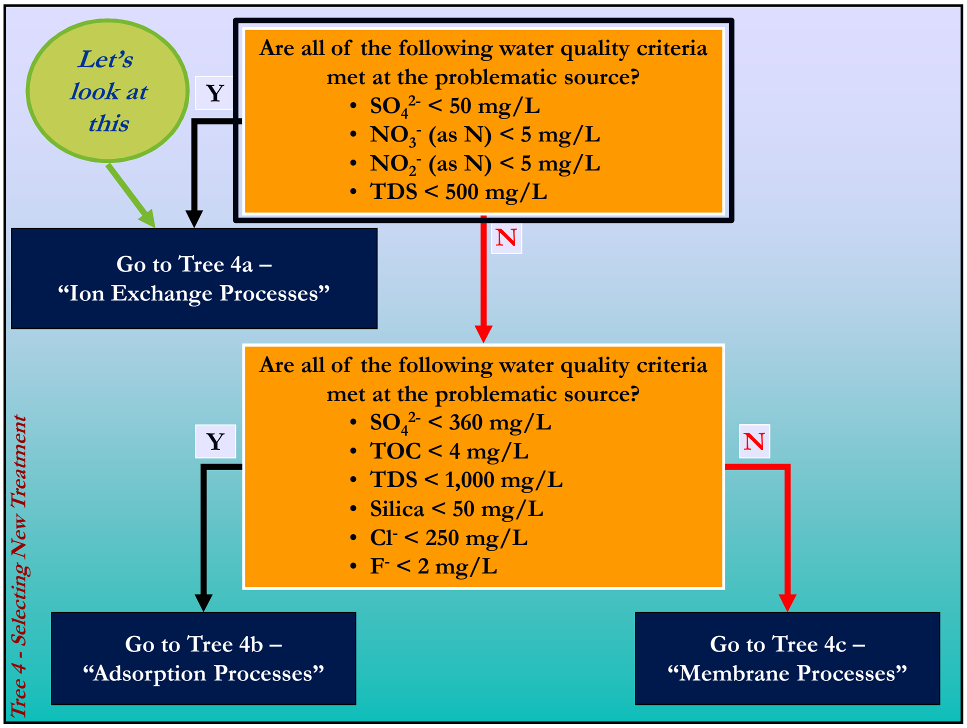
1. Ion Exchange
2. Membrane
3. Adsorption

Raw Water Testing

- Primary parameters
  - Total Arsenic, Arsenite, Arsenate
  - Chloride
  - Fluoride
  - Iron
  - Magnesium
  - Manganese
  - Nitrate/Nitrite
  - Orthophosphate
  - pH
  - Silica
  - Sulfate
  - Total Dissolved Solids (TDS)
- Secondary parameters
  - Alkalinity
  - Aluminum
  - Calcium
  - Turbidity
  - Hardness

Arsenic Treatment & Water Quality

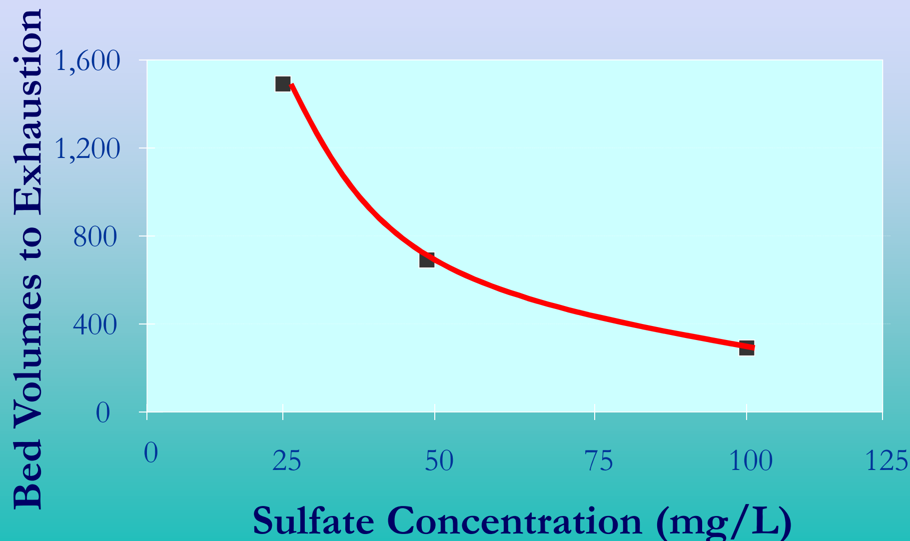
Parameter	St. George	Magna
Total Arsenic	24.5 ppb	11.3 ppb
Iron	0.1 mg/L	0.069 mg/L
Manganese	<0.01 mg/L	0.066 mg/L
Total Silica	21.5 mg/L	70 mg/L

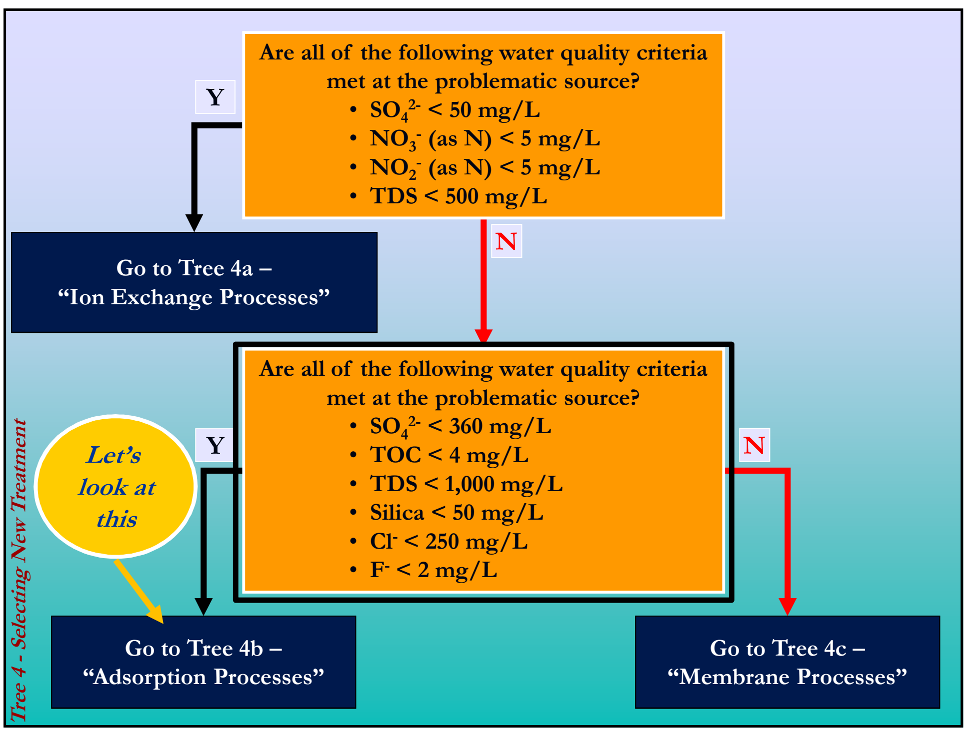


Ion Exchange for Arsenic Removal

- Ions exchanged between a solution phase and solid resin phase
- Exchange affinity
  - Sulfate, TDS, selenium, fluoride, nitrate
- Insensitive to pH
- Consider waste by-product disposal
- Suitable for small GW systems with low sulfate and TDS and as the polishing step after filtration

Effect of Sulfate on Ion Exchange





Adsorption Processes

1. Activated Alumina (AA)
2. Granular Ferric Hydroxide (GFH)

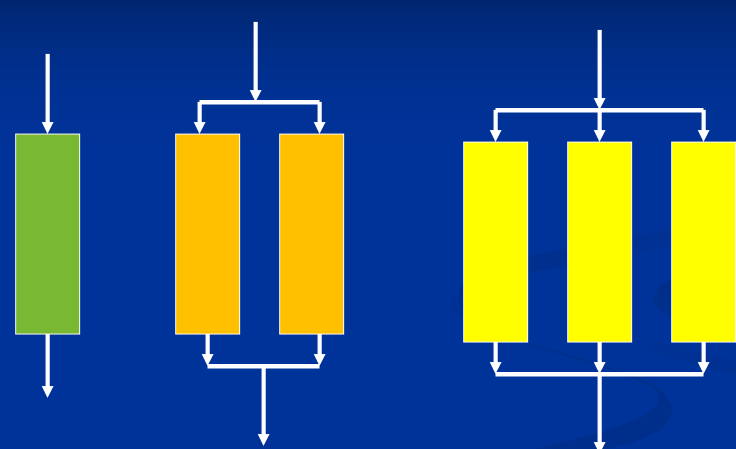
Activated Alumina

Delta City

Granular Ferric Hydroxide

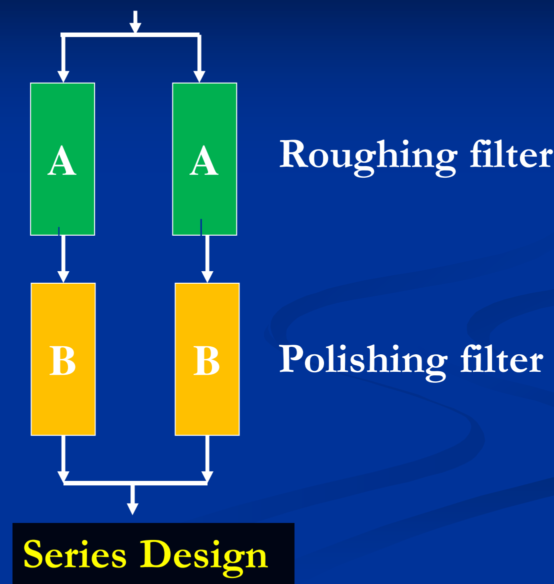
Activated Alumina System

Adsorptive Media System Design



Simple 1, 2, or 3 beds in parallel

Adsorptive Media System Design



Are all of the following water quality criteria met at the problematic source?

- SO_4^{2-} < 50 mg/L
- NO_3^- (as N) < 5 mg/L
- NO_2^- (as N) < 5 mg/L
- TDS < 500 mg/L

Y: Go to Tree 4a – "Ion Exchange Processes"

N: Are all of the following water quality criteria met at the problematic source?

- SO_4^{2-} < 360 mg/L
- TOC < 4 mg/L
- TDS < 1,000 mg/L
- Silica < 50 mg/L
- Cl^- < 250 mg/L
- F^- < 2 mg/L

Y: Go to Tree 4b – "Adsorption Processes"

N: Go to Tree 4c – "Membrane Processes"

Let's Look at This

Tree 4 - Selecting New Treatment

Membrane Processes

- RO
- Nanofiltration
- Coagulation Assisted Microfiltration

Conclusions

- Treatment is only one of the many mitigation options
- Iron removal → arsenic removal
- Arsenic speciation and oxidation are important
- Water quality affects selection & performance of arsenic treatment

Questions?

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